Lightweight, Mobile E-Mail for Intra-Clinic Communication

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We have developed a mobile messaging system designed for use in the clinic setting. The system is designed to facilitate quick, informal, interactions that occur in a clinical setting, e.g., requests for assistance or information. The system includes safeguards to make sure that the sender of a message is aware if a message is not read in a timely fashion. Evaluation of the system shows message delivery was about 50% slower than our target of 30 seconds. Although the mobile device used is fairly small when combined with a radio unit, it is too bulky and users did not necessarily carry the system with them. This led to delays (over eleven minutes on average) before messages were seen. We expect that improvements in hardware and clinical software will lead to more common use of such adjunct software systems.

INTRODUCTION

As work progresses on building computerized aids for handling medical information, we have begun to investigate how emerging computer technologies can be used to facilitate some of the more routine tasks involved in clinical settings. For instance, an important component of information flow in clinical settings is the short, often abbreviated messages that flow between practitioners as they deliver care. These are passing-in-the-hall messages such as "Mr. Smith is ready in room 3." or "Please give Ms. Jones her shot." Such messages are used to coordinate tasks between caregivers.

Coordination messages are typically very short since both parties are quite familiar with the context. The messages are typically one-way, although acknowledgement is often required.

A problem is that it is difficult to relay coordination messages efficiently since the recipient may be out of reach. The process of finding and interrupting the other person in order to deliver a message can lead to wasted time and reduced efficiency for both clinicians and patients.

To see if the process of passing coordination messages could be improved, we built an experimental communication system using small, hand-held computers and wireless local area networking. The system was deployed in an outpatient general medicine clinic for use by doctor/nurse teams in passing coordination messages to each other.

This task is one of many we envision being addressed as an *adjunct* to a much broader clinical computing system, incorporating electronic patient records, results reporting, order entry, decision support, literature access, etc. As clinical computing systems become widespread, the marginal cost of integrating and using adjunct systems such as this will become low.

BACKGROUND

In our initial survey of clinicians, they reported an average time of three minutes to deliver a coordination message in person, starting from when the initiator decides to deliver the message and ending when the initiator has confirmation that the message has been received.

Attempts to solve the coordination problem have taken several forms as clinicians have become more specialized and independent. Overhead paging systems can help track down another clinician, but require team members to meet somewhere to exchange information for all but the simplest messages. Overhead paging also adds to the background noise level. Intercom systems reduce travel time since parties can converse at a distance, but typically require briefly interrupting everyone in the clinic to start a conversation, as well as significantly distracting the recipient.

Several experimental systems have been built to try to meet medical communication needs. One system uses wireless telephones carried by the nursing staff.[1] Rather than cellular phones, they chose small, portable telephone similar to cordless phones found in many homes. Nurses on two medical-surgical units were studied before and after being given telephones. Nurses reported increased satisfaction with the system and were found to experience fewer interruptions to patient care. A time and motion study verified the expected decrease in time to locate a nurse and a decrease in time spent waiting at the nursing station for a returned page.

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Another system used radio systems carried by nurses.[2] Rather than using telephone technology, the group at Rush-Presbyterian-St. Luke's in Chicago used radio transceivers worn by the nurses, and a central base station. Users could speak to the base station or send an emergency alert to all personnel, but could not speak directly to each other. Pre- and post-intervention data were collected including the number of overhead pages, as well as distance walked and overall noise level. Overhead paging decreased 72% and providers perception was that the noise level was significantly decreased. Benefits included quicker updates to patient information, easier location of nursing staff, and less time spent responding to incorrect signals, although the total walking distance was the same.

The most widely used approach today is a system of colored lights. Light are able to convey a message with minimum interruption to the recipient and others in the clinic since there is no need to break off the task at hand to receive the message. However, such systems can be quite confusing as they become more complex since users must learn the code used, and the number of different messages that can be sent is very limited.

At the other end of the spectrum, some clinical computing systems support sending traditional electronic mail. This provides substantial flexibility in that any message can be sent, but such systems are directed more at standard uses of e-mail, which often doesn't support convenient, fast-turnaround, short messages. Typical impediments include the need to login, start the e-mail program, enter complex addresses, and use a keyboard. Further problems include not being able to confirm that a recipient has seen a message and difficulty reaching someone moving around the clinic unless that person is constantly logging in at each new location.

The system described in this paper attempts to deal with many of these issues, as well as to provide a tool for gathering information about how clinicians communicate.

DESIGN CONSIDERATIONS

Mobility is the key characteristic of our design. Messaging could in principle be delivered via terminals built into the infrastructure of the clinic, but such an approach would face considerable difficulty in providing the necessary convenience, privacy, and notification. Devices that move around with clinicians make it possible to maintain privacy by holding the device so others cannot see the display. Since a mobile device is with the user, notification via minimally intrusive sounds can be used, and the near-to-hand nature improves convenience as well.

We took the user reported three-minute average interaction time as a design upper bound on the performance of our system; we wanted the start-of-composition to message-read time to be under three minutes. This led to the following characteristics:

Convenience of composition
No extraordinary skills or training should be necessary to compose and send a message. Tasks such as signing on to a workstation, or skills such as operating a code system, or typing would all be impediments to messaging. In order to be carried easily by clinicians, our system had to be very small. This tends to favor use of handheld, pen-based devices.

Speed of transport
Based on design discussions with clinicians, we targeted 30 seconds as the maximum delay from when the sender is done composing until the message is available to the receiver.

Notification
The system has to notify recipients of received messages carefully. If the system is too insistent, like typical pagers, interactions with other people will be disrupted. If it is too timid, messages will go unseen.

Convenience of reading
Just as impediments to composing a message could prevent utilization of our system, requirements such as logging in, mastering a code system, or travelling to a pick-up point to receive a message would reduce the effectiveness of the system.

Confirmation of Receipt
Knowing that a message has been received and is being taken care of is a key concern of clinicians. However the need to acknowledge explicitly every routine message would be an imposition for recipients, so automatic acknowledgments are desirable.

Privacy
Although coordination messages are informal, they may still contain sensitive information, and therefore need to be kept private. Broadcast systems and even workstation screens make it difficult to keep nearby people from seeing the contents of messages. Our design should make privacy easier to maintain, although, as with any electronic conveyance of patient data, encryption or other mechanisms should be used to guard against unauthorized interception.

Although we anticipate messaging systems like ours will be used in the context of computerized record systems, we believe the content of such informal messages should not become part of the medical record,

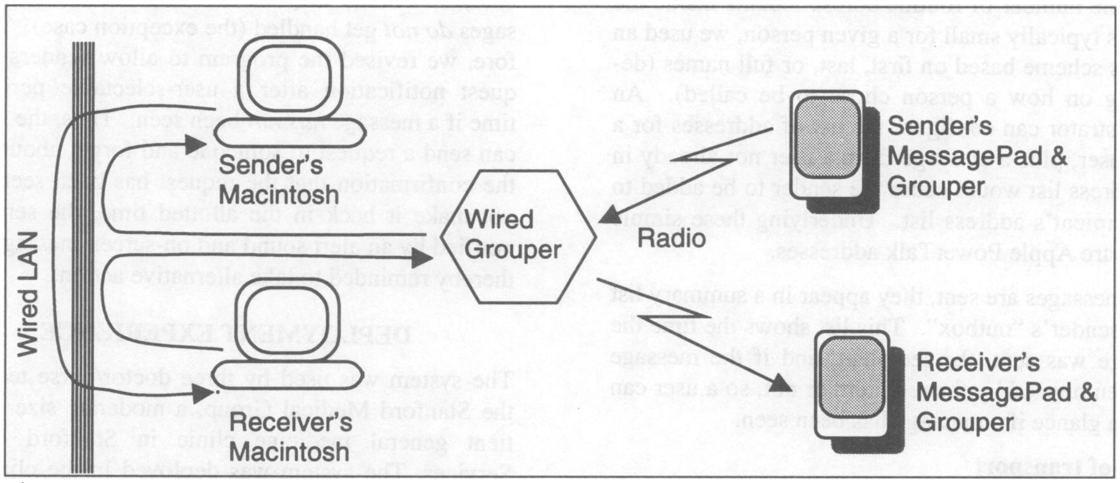

Figure 1: System Architecture

just as verbal communication is considered informal and outside of the record today.

Networking
Of course, wire-based networking between the mobile devices would not work. Also since the battery-powered mobile devices need to be continually "listening" for incoming messages, the low power consumption of a wireless local area network (LAN) is important.

SYSTEM DESCRIPTION

Since the system has to be both fast and easy to use, it has to have the minimal user interface necessary to get the job done, but not require substantial training to use. This motivated a careful design of the actual graphical user interface, and led us to use untranslated handwriting (digital ink) for the body of messages since handwriting recognition is slow, awkward, and unreliable for most novice users of current pen-based devices.

Each user is assigned a handheld pen-based device. To send a message, the user selects a recipient(s) from a list, handwrites the message on the screen, and taps a "Send" button. Moments later, the recipient's device makes a sound. If the message remains unseen for a long time, the system plays the sound again.

Architecture
Our experimental system, called "Note Passing", is an application on the Apple Newton MessagePad. Each MessagePad is linked to a dedicated Apple Macintosh computer via a Digital Ocean Grouper™ on a wireless LAN.

The handwriting stroke information is encoded into a character string suitable for email and handed to an application called "AOCE Mail" for transport to the recipient's MessagePad. AOCE Mail is an experimental program built at Apple Computer's Advanced Technology Lab as part of the Apple Open Communication Environment. The Grouper is a device about the size of the MessagePad that clips onto the MessagePad. It is a simple network router that relays the LocalTalk messages from the MessagePad over very low power radio to another Grouper connected to the clinic's wired LAN. See Figure 1.

Our system also supports control messages that can be used to perform such tasks as retrieving usage statistics or updating address lists.

Networking Disconnects
Since the system uses wireless networking and battery powered devices, it is a fact of life that there will be times when devices are disconnected from the rest of the network. Our system is designed to tolerate such conditions well. Any messages directed to the disconnected device are stored on the associated Macintosh until the device reconnects

Our application on the mobile device monitors connectivity to the network and displays connection status. If connectivity is lost, the application automatically attempts to reconnect in the background. If it cannot reconnect in a specific amount of time, it alerts the user via a sound and dialog so that the user may take corrective action.

Convenience of composition
In normal use, there is always a "New Message" button that can be used to start composing. The user picks the recipient's name from a list, and then can write a note. There are buttons to set priority and request notification of non-receipt, as well as the "Send" button. No user reported trouble composing messages.

Since the number of routine corespondents inside the clinic is typically small for a given person, we used an address scheme based on first, last, or full names (depending on how a person chose to be called). An administrator can configure the list of addresses for a given user, plus a message from a user not already in the address list would cause the sender to be added to the recipient's address list. Underlying these simple names are Apple PowerTalk addresses.

After messages are sent, they appear in a summary list in the sender's "outbox". This list shows the time the message was sent, the recipient, and if the message has been opened by the recipient or not, so a user can tell at a glance if a message has been seen.

Speed of transport

Despite the many layers and steps of the message transport system used, we were able to meet the goal of 30 seconds to deliver a message in testing. However, during deployment delivery time averaged 47 seconds for reasons discussed later.

Privacy

The small size of the MessagePad makes maintaining privacy simple, as long as the system is kept with the user. Users would leave the MessagePad on their desks, just as charts, and other notes, are left, but they did not leave it in exam rooms or other places where privacy could more easily be compromised.

Notification

A non-intrusive tone is sounded for normal priority messages, and a more urgent sound for high priority messages. If a message is not viewed in a certain period of time, another tone is sounded. There is no audible alert (by default) for low priority messages.

Convenience of reading

When the system is idle, the Notes Passing application displays the *inbox* and *outbox*. The sender, time sent, and status of each received message is displayed in the inbox. Messages that haven't been read are highlighted in the inbox. The contents of the message are displayed when the user taps on the message. A control message is then automatically sent to the sender indicating that his message has been seen.

A reply can be sent, with or without including the original message. After viewing, the user can delete or keep the message.

Non-Receipt Alert

In our first implementation, we included a "return receipt" capability as is found in many commercial e-mail systems, thinking that users would use it to confirm messages had been read. We quickly realized that this is backwards—what users really want to know isn't that a message got through ok (the normal case), but rather they want to know when their messages *do not* get handled (the exception case). Therefore, we revised the program to allow senders to request notification after a user-selectable period of time if a message *has not* been seen. Thus, the sender can send a request to someone and forget about it. If the confirmation that the request has been seen does not make it back in the allotted time, the sender is notified by an alert sound and on-screen message, and thereby reminded to take alternative action.

DEPLOYMENT EXPERIENCE

The system was used by three doctor/nurse teams at the Stanford Medical Group, a moderate size outpatient general medicine clinic in Stanford Health Services. The system was deployed in the clinic for approximately 20 days. In order to insulate users from the idiosyncrasies of the hardware and software being used, one of our team members delivered fully charged and set up units at the beginning of the shift and was on site to answer any questions. Not all teams were active on all days. A total of 66 messages were sent. A questionnaire was used to collect information from the users regarding their experience with the system.

Step	Mean (m:s)	St. Dev.
Compose	0:53	0:54
Deliver	0:47	0:20
Read	11:09	18:48

Table 1: Timing data

Message composition generally took about one minute, which was in keeping with our expectation (see Table 1).

Message delivery took an average of 47 seconds, which is more than the 30 seconds we had planned. Although using the transport mechanism from Apple simplified implementation and statistics gathering, its impact on the performance of the system is substantial and future experiments would likely require replacing it with a simpler and faster hub-based message router.

The time between when a message was available and when it was actually read averaged more than 11 minutes. Despite our efforts to provide a highly mobile device, we found that the clinicians typically left the device on their desks while performing tasks, thus defeating the idea of the mobile device. Users unanimously cited the size and weight of the MessagePad/Grouper unit as the primary reason they did not take the device with them.

While the overall size was considered too large, in the post-deployment survey, all users described the screen area available for viewing and writing as "right size" or very near it. Despite the reputation for poor handwriting held by doctors, users rated the legibility of the notes they received as high.

The message priority function was not used at all. The primary reason cited was "didn't need it." We suspect that if the system were used routinely at higher volume, the priority function would become more useful.

Categories of Messages

The messages sent during the deployment fell into these categories:

Count	Message Type
29	Rooming patients
13	Scheduling
5	Personal
4	Task assignment
4	Lab test request/results
4	Phone call coordination
3	Administrative
1	Reminder to self

LESSONS LEARNED

All of the participants rated the system at least moderately useful. Not surprisingly, however, this communication system by itself was not enough to justify carrying a device around. That lack of presence was reflected both in the overall usage level of the system, as well as in the long time taken to process messages.

As more clinical functions are designed and built for mobile systems their aggregate usefulness should motivate clinicians to carry the devices as they move about the clinic. We believe that at that time systems for intra-clinic communication such as this will become substantially more useful. The on-going improvement in mobile computing systems, resulting in reduced size and weight with increased performance and battery life, is lowering the threshold of how much a device must be able to do in order to be worth using in a clinic.

Although our system resembles traditional electronic mail systems, there are significant differences. For instance, the ability to guarantee very fast delivery must be considered in an intra-clinic system. Message-not-read alerts and multi-mode audible notification are not typical either, but both are very important to good intra-clinic communication.

A MessagePad-sized device seems to serve well for this type of communication, with adequate screen area and legibility. The users rated the speed of the system as acceptable. However, we believe that if use were to become more routine, they would feel constrained by the current speed of delivery.

FUTURE WORK

The additional functions most desired by the clinicians were, first, prescription writing and test results retrieval, with e-mail outside the clinic, scheduling, patient information, and access to reference materials further down the list.

Technically, the system could be improved by changing to a single-hub architecture to improve performance and reliability. This would also ease future interoperability with traditional e-mail systems.

We designed the system to support adding templates so that as the system was used, common types of messages could be facilitated by selecting an appropriate template and filling in the blanks.

CONCLUSION

Our Note Passing system shows promise as a way for clinicians to pass routine messages to each other as they move about the clinic in the short-term, and as a way to mediate more general kinds of communication, information access, and decision support in the longer term. The system addresses many of the problems in existing intra-clinic communication systems by providing a mobile, wireless notepad connecting team members, wherever they are in the clinic. Usage rate and system performance were less than our design goals due to the size of the Newton PDA with radio pack, causing users to not carry it. Lighter weight and better integrated hardware should alleviate this problem. Wider availability of clinical software will provide an environment where tools such as this will be used more routinely.

Acknowledgments

This work has been partially supported by the CAMIS Resource, NLM # LM-05305. We thank Apple Computer and especially Dan Gerson and Greg Whitehead of Apple Computer.

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